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Bezeichnung der Erfindung/Title of the invention/Titre de l'invention:
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Low power dissipation information recording apparatus

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Field of the invention

The invention concerns an information recording apparatus intended to record information on an optical medium by forming series of recorded marks whose length between leading edge and trailing edge corresponds to a binary value by means of irradiation with a beam of light. The invention relates also to an information recording method.

Background of the Invention

Such an information recording apparatus is known from US6426930. This document presents, for example, in the description of the prior art, an apparatus and a method to record information on an optical medium by forming series of recorded marks whose length between leading edge and trailing edge corresponds to a binary value. This prior art describes a conventional write strategy for optical discs. Figure 1 reproduces a figure describing the prior art in said document. Figure 1 describes the writing of three successive marks MK2, MK3, MK4 on a track TRK of an optical disc, each mark representing an information B of two B2, three B3 and four bits B4 in time T. According to this conventional strategy, the writing of a continuous mark of N bits needs a conventional pulse pattern of N-1 pulses having different intensity and different duration. Said pulses of at least one high laser current write level HWL are generated from a bias level BL close to a threshold level TL. Said threshold level TL is defined by the threshold current creating necessary population inversion. This population inversion is a minimal condition to obtain a coherent light emission. This is illustrated on figure 2. This last figure depicts the light power emitted by the laser LP as a function of the laser current LC. The laser current LC consists of two parts: a relatively large threshold current TC that is not related to the light power LP being emitted, but is needed to create the population inversion and a delta current DC that is proportional to the light power LP being emitted by the laser diode.

According to the conventional strategy presented on figure 1, the average laser current in time is high as this laser current LC is always above the threshold level TL. Consequently large power dissipation occurs in the laser diode during the writing of an optical disc. It has to be noted that, in N strategy, pulses are raised from a bias level and all along a pulse the laser current is maintained at a high level generating high power dissipation.

Summary of the Invention

It is an object of the present invention to propose a new writing strategy and new apparatus to record information on an optical disc keeping the power dissipation low.

To this end, the invention proposes an information recording apparatus as presented in the introductive part, characterized in that said means of irradiation are sequentially pulsed to at least a high laser current write level from a low laser current level close to zero during the writing of a recorded mark. Said means of irradiation are generally pulsed at a writing frequency, that can be constant.

The invention then allows to reduce the average laser current by the presence of said low level close to zero or equal to zero to which is periodically switched the laser. The average light power being emitted during writing by the laser diode can effectively remain the same while the average laser current is reduced. The invention is only restricted by the rapidity of the laser diode and of the laser driver.

The reduction of the power dissipation resulting from the invention is particularly advantageous for newly developed solutions for portable applications where the storage capacity has to be high while presenting very small dimensions and for which the power dissipation has to be kept low. For example, small form factor optical (SFFO) disc systems would be particularly concerned by the invention.

Another problem in prior art is that, during erasing, referring to figure 1, the laser diode is supplied with a current that defines a high laser current erase level HEL rising from the bias level BL. It has also to be noted that, in conventional strategy, even if the high laser current erase level HEL is inferior to the high laser current write level HWL, the high laser current erase level HEL is another source of the rising of the average laser current.

According to an advantageous embodiment of the invention, an apparatus of the invention is characterized in that means of irradiation are pulsed to a high laser current erase level from said low level during the erase of a recorded mark. Generally said means of irradiation are pulsed at an erasing frequency that can be advantageously constant.

According to a preferred embodiment of the invention, the bias level is equal to said low level LL.

The invention also relates to an information recording method that is advantageously implemented in an apparatus of the invention.

Brief Description of the Drawings

The invention is described hereafter in detail in reference to the diagrammatic figures wherein:

Fig.1 presents a conventional writing strategy according to the state of the art;

Fig.2 depicts the laser light power as function of laser current;

Fig.3 illustrates a writing strategy according to an embodiment of the invention;

Fig.4 illustrates a function that is multiplied according to the invention to a conventional pulse pattern;

Fig.5 illustrates a writing strategy according to an advantageous embodiment of the invention;

Fig.6 illustrates a writing strategy according to a preferred embodiment of the invention;

Fig.7 is a schematic diagram of an apparatus according to the invention.

Description of embodiments

Fig.1 and 2 have already been described hereinabove in the description of the prior art. The first pulse pattern described on figure 1 corresponds to known technical constraint and is called conventional pulse pattern in the following. This conventional pulse pattern is constituted of N-1 pulses for a mark of N bits. Indeed marks are of a minimum of two bits according to the classically used coding (17-PP coding) or of three bits (EFM, EFM+) on optical medium. N-1 strategy is used for the description of the invention; nevertheless the invention concerns any writing strategy, including N strategy. Said coding is realized before writing on said optical medium that is generally a disc but that can be any other form of optical format including magneto-optical-, phase change- and dye-recording. It is known that the minimum number of channel bits per mark is for CD (EFM coding) three, for DVD (EFM+ coding) also three and for blu-ray disk/SFFO (17-PP coding) two. In such cases, no one bit marks are required. The leading edge corresponds to the beginning of the mark that represents the first bit and trailing edge corresponds to the end of the last bit of the information represented by the mark. If one bit marks are required, the leading edge corresponds to the beginning of the mark that represents the single bit and trailing edge corresponds to the end of said bit.

Figure 3 describes a first embodiment of the invention applied to the conventional pulse pattern proposed on figure 1. The invention aims in reducing the average laser current in time in order to reduce the power dissipation in the writer. In the prior art, the average laser current is compulsory higher than the threshold current as the laser current is all the time greater than this threshold current. Great power dissipation thus occurs. A way to reduce the average current is to pulse the laser during writing by switching it off periodically. During the time the laser is switched off, the laser current is near zero or equal to zero. Correct marks can be obtained by switching off the laser with a frequency allowing to divide again pulses of the first pulse pattern in several shorter pulses that rise from zero to at least a high laser current write level IHWL. Consequently it is possible to reduce the average laser current. The invention thus proposes to switch the laser, for example according to a given frequency called writing frequency, during the writing of a recorded mark MK.

On figure 3, the conventional pulse pattern is represented by a dotted line while a writing strategy according to the invention is represented by a plain line. The writing strategy according to the invention is then advantageously obtained by a multiplication of the conventional pulse pattern with a second pulse pattern having a given frequency, for example a constant one. Said multiplication is, advantageously and in conformity with figure 3, realized only during pulses at high write level HWL of the conventional strategy, and not during bias level periods of said conventional strategy. According to the invention, it is necessary that the writing frequency of the multiplied second pulse pattern is higher than the maximum frequency at which level changes occur in a conventional strategy as illustrated on figure 1. The frequency of this second pulse

pattern is frequency and phase locked to the conventionally used clock or a multiple of said clock. The start of a write level in the conventional strategy should coincide with a rising edge in the newly obtained pulse pattern. One may have to tune the timing of the first laser current pulse of the write strategy according to the invention such that the rising edge of the light output of the first pulse coincides with the rising edge of the light output of the first pulse in the conventional strategy. The second pulse pattern is illustrated on figure 4 and is thus such that the pulses are raising from a low level LL to a high level HL. High and low levels each corresponds to respective laser current intensity. The frequency is represented as a constant frequency but the invention can use any other second pulse pattern that can be multiplied to a conventional pattern in order to have pulses raised from a low level close or equal to zero to a high level, said pulses having a more important occurrence than in conventional strategy pulse pattern. Any sequence of pulses allowing this last feature is allowed according to the invention.

The second pulse pattern multiplied with conventional pulse pattern should have a high level HL higher than 1 in order that a same average delta current is obtained during the time a mark is written. Effectively, if the same average delta current is obtained, the same average light power is also obtained during the writing of a mark. Thus a correct mark on the optical medium is obtained. The low level LL of the multiplied second pulse pattern may be zero current, as shown on figure 4, or a relatively small current of the scale of a few mA. Such a low level LL reduces the threshold current savings somewhat but also reduces the rise time of the laser current. This is important as a shorter rise time can reduce jitter. A high laser current write level IHWL is then obtained. This high write level IHWL of the obtained new pulse pattern after multiplication is then higher than the one HWL of the conventional pulse pattern.

A duty cycle D is defined as the fraction of time per pulse period of said multiplied second pulse pattern, as illustrated on figure 4, that the laser is on. A duty cycle D of 25% would for instance mean that the laser is on 25% of the time per period. D=50% seems to be an optimal duty cycle D. It means that the duration during which the laser is at the high laser current write level IHWL is the same as the duration during which the laser is at the low level. Said duty cycle can nevertheless be chosen different. Effectively smaller duty cycle allows more power savings. Smaller duty cycles can nevertheless lead to increased jitter.

Then, the achievable power reduction is dependant on the duty cycle, on the threshold current, on the low level and on the losses in the internal capacitance associated with the laser due to the switching. The average light power reaching the optical medium is assumed to be the same. This is not a necessary assumption. This assumption means that if pulses with duty cycle of 50% are realized, the delta current should be twice as high, resulting in the same average light power being emitted. By pulsing the laser according to the invention threshold current is gained. The amount of threshold power that is saved when pulsing with a low level LL of zero is (1-D) times the threshold power.

Thus, if a conventional pulse pattern is used and a duty cycle D is applied on the second multipled pulse pattern, the power P savings is expressed by:

$$\Delta P = P_{laser,continuous} - P_{laser,pulsed}$$

Indeed according to the explanations above, what is saved is a fraction (1-D) of ($P_{threshold}$ - P_{low}) with P_{low} being the low level LL of the pulses when pulsing and $P_{threshold}$ the threshold level. It has also to be noted that pulsing the laser also costs some additional power $P_{cap,laser}$ because an internal capacitance in the laser needs to be charged and discharged more often. It represents the creation and destruction of population inversion. This charging and discharging does not contribute to the light power being emitted and is just lost. So to calculate the real saving this $P_{cap,laser}$ has to be subtracted from the power savings as calculated above. Hence, power saving is indicatively expressed by:

$$\Delta P \doteq (1-D).(P_{threshold} - P_{low}) - P_{cap,laser}.$$

It is possible to reduce the capacitive losses in the laser by choosing a resonant laser driver. Effectively such capacitive losses are a drawback for pulse patterns obtained according to the invention as the laser is switched off while they are less a problem for the conventional pulse pattern where the laser pulses are risen from the bias level close to the threshold level.

A minimum duty cycle of 50% is allowed without any jitter increasing. According to a most preferred embodiment of the invention the duty cycle is thus D=50%, especially for erasing.

An additional advantage of the invention is that jitter and crosswrite may be reduced and DOW cyclability increased.

Figure 5 describes an advantageous embodiment of the invention where means of irradiation are pulsed at an erasing frequency to a high laser current erase level IHEL from a low level LL close or equal to zero during the erase of a recorded mark. The erasing frequency is represented on figure 5 as being lower than said writing frequency. This erasing frequency can be different, higher or lower, or equal to said writing frequency. The new erase pulse pattern is obtained by a multiplication of the conventional erase pulse pattern, that is conventionally a single continuous pulse, with a second pulse pattern of a constant frequency, rising from a low level LL to a high level HL preferably slightly higher than 1, as shown on figure 4. This second pulse pattern has to be frequency and phase locked to the conventionally used clock or to be a multiple of it. Said second pulse pattern can also be any pulse pattern that can be multiplied to a conventional pattern in order to have pulses raised from a low level close or equal to zero to a high level, said pulses having a more important occurrence than in conventional strategy pulse pattern. Again the start of the rising of an erase level in the conventional strategy should coincide with a rising edge in the new obtained pulse pattern. Said bias level BL can also been multiplied by a second pulse pattern as presented on figure 4. In this case, pulses of a constant bias frequency appear on figure 5 also during the duration BD illustrated by an arrow on said figure 5.

Figure 6 describes a preferred embodiment of the invention. According to this preferred embodiment, the bias level BL is equal to the low level LL in order to further reduce the power dissipation.

It has to be noted that reducing the average laser current can help to reduce problem of cross-write that occurs when some light falls on a neighboring track deteriorating the marks/spaces already written in that neighboring track. This can also lead to lower overall jitter that is the amount of deviation from the intended position of the mark edges or boundaries. So the information storage/record is of better quality. The invention can also allow to increase the Direct Over Write cyclability that is a number that indicates how many times a re-writable optical medium can be written and erased.

Figure 7 is a schematic diagram of a recording apparatus of the invention. In this apparatus an optical medium that is for example a disc DSK is disposed in order to face an optical pickup unit OPU. Information INF to be recorded on said disc DSK is provided by an input terminal IT to an automatic laser power controlling mechanism ALP. Said information INF is considered to be already coded by a coding module CM placed before said input terminal. Said mechanism ALP controls the power of the laser light emitted from the optical pickup unit OPU. Thus, said mechanism ALP provides a laser diode circuit with a signal that will control the laser current provided to said laser diode. Said signals depend on the inputted information INF. Thus according to the invention, said signals implies that the laser current is pulsed and consequently that laser light is emitted from the optical pickup unit OPU. For example, according to the first embodiment of the invention illustrated by figure 3, signals formed within said mechanism ALP are the multiplication, during each writing duration, of a conventional pulse pattern CPP known for the writing of binary values present in inputted information INF (at least two or three bits as seen before) with a second pulse pattern SPP as shown on figure 4.

Presented figures are illustrative of special embodiments of the invention and are not restrictive. Effectively, the invention can, for example, be implemented by multiplying a second pulse pattern as described hereinabove in figure 4 with any style of pulse pattern allowing the writing of a mark. In a simple example, the conventional pulse pattern is not pulsed with N-1 pulses but is simply constituted of a rising to a high level followed by a decreasing to a low level.

It will be apparent to those skilled in the art that many modifications and variations may be made to the exemplar embodiments of the present invention set forth above, without departing substantially from the principles of the present invention. For example, the present invention can be used with any optical record carrier of any format. All such modifications and variations are intended to be included herein.

Claims:

1. An information recording apparatus intended to record information on an optical medium by forming series of recorded marks whose length between leading edge and trailing edge corresponds to a binary value by means of irradiation with a beam of light characterized in that said means of irradiation are sequentially pulsed to at least a high laser current write level from a low laser current level LL close to zero during the writing of a recorded mark.

2. An information recording apparatus as claimed in Claim 1, wherein said low laser current level LL is equal to zero.

3. An information recording apparatus as claimed in Claim 1, wherein said means of irradiation are sequentially pulsed to a high laser current erase level from said low laser current level close to zero during the erasing of a recorded mark.

4. An information recording apparatus as claimed in Claim 1 or 2, wherein a bias level is reached during time intervals different of writing and/or erasing time intervals, and wherein said bias laser current level is substantially equal to said low laser current level.

5. An information recording method for recording information on an optical medium by forming series of recorded marks whose length between leading edge and trailing edge corresponds to a binary value by means of irradiation with a beam of light, characterized in that it includes a step of sequentially pulsing said irradiation means to a high laser current write level from a low laser current level LL close to zero during the writing of a recorded mark.

6. An information recording method as claimed in Claim 5, wherein said low laser current level LL is equal to zero.

7. An information recording method as claimed in one of the Claims 5 and 6, wherein it includes step of pulsing said means of irradiation to a high laser current erase level from said low laser current level close to zero during the erasing of a recorded mark.

8. An information recording method as claimed in one of the Claims 5 to 7, wherein a bias level is reached during time intervals different of writing and/or erasing time intervals,

and wherein said bias laser current level is substantially equal to said low laser current level.

"Low power dissipation information recording apparatus."

Abstract:

The invention relates to an information recording apparatus intended to record information on an optical medium by forming series of recorded marks whose length between leading edge and trailing edge corresponds to a binary value by means of irradiation with a beam of light. According to the invention, said means of irradiation are sequentially pulsed to at least a high laser current write level from a low laser current level LL close to zero during the writing of a recorded mark.

The invention enables to lower the average laser current during writing and also erasing. As a consequence the power dissipation is lowered.

Application: Information recording apparatus, especially for SFFO, BluRay standards.
FIG. 3

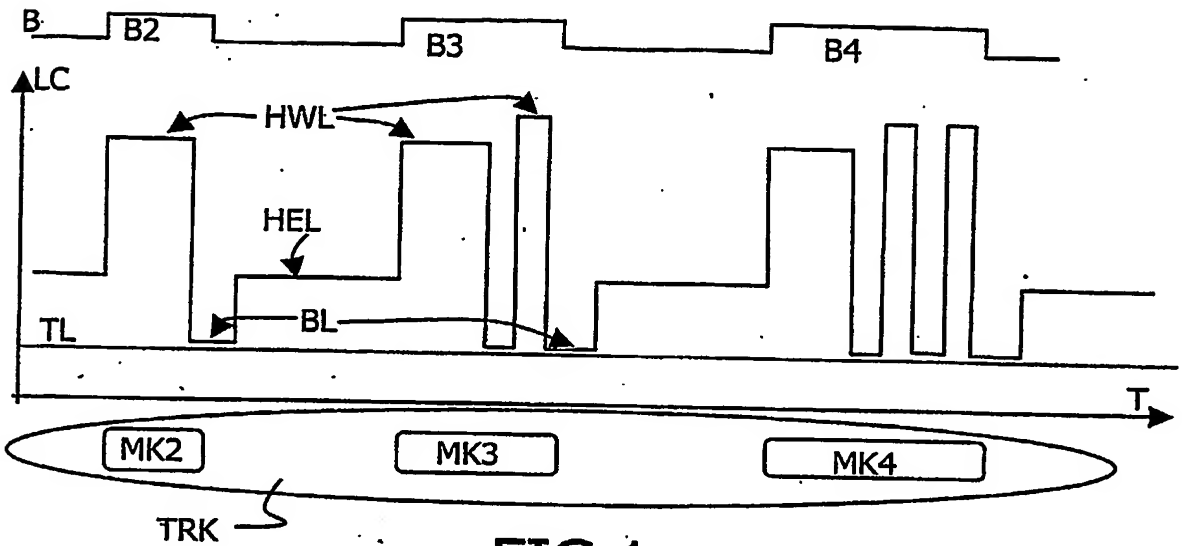

FIG.1

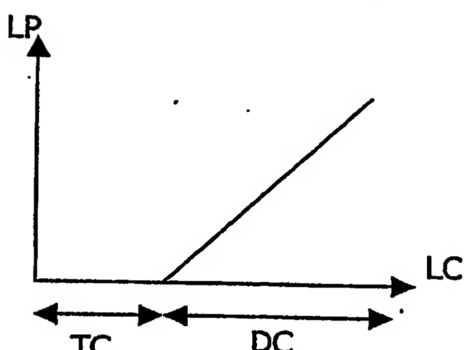

FIG.2

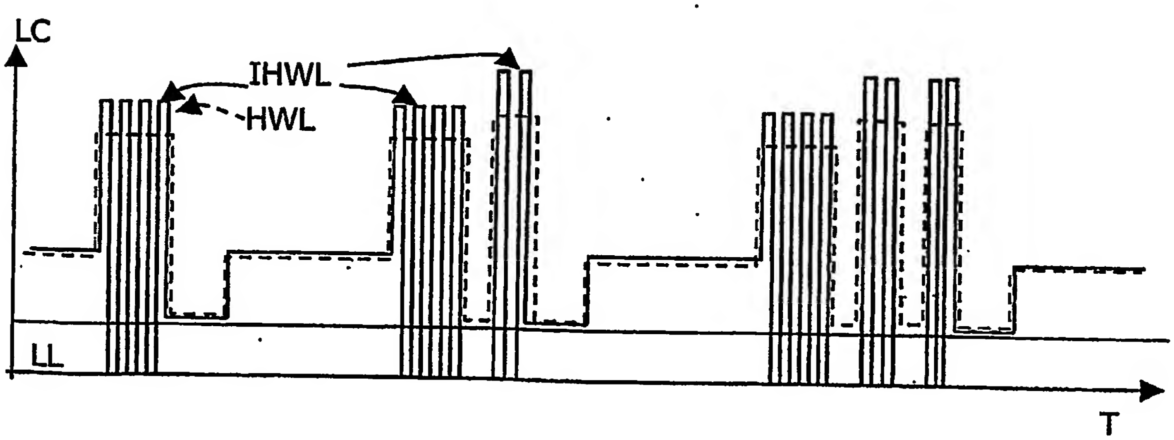

FIG.3

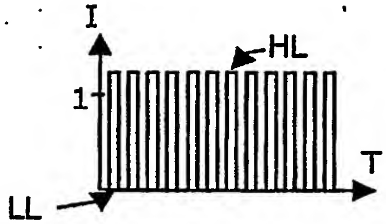

FIG.4

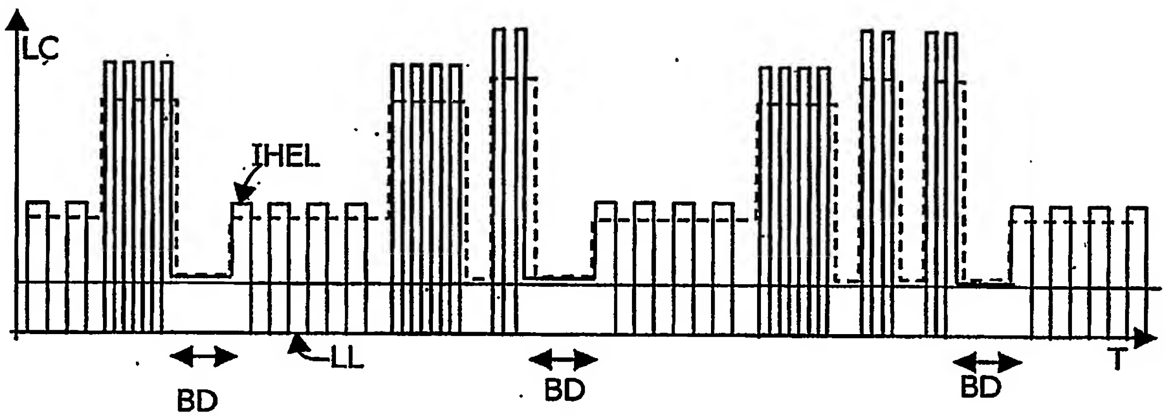

FIG.5

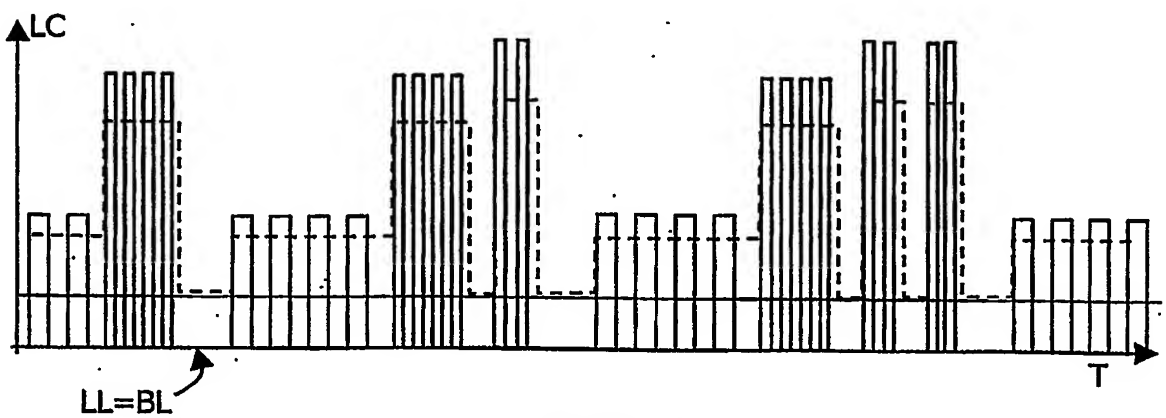

FIG.6

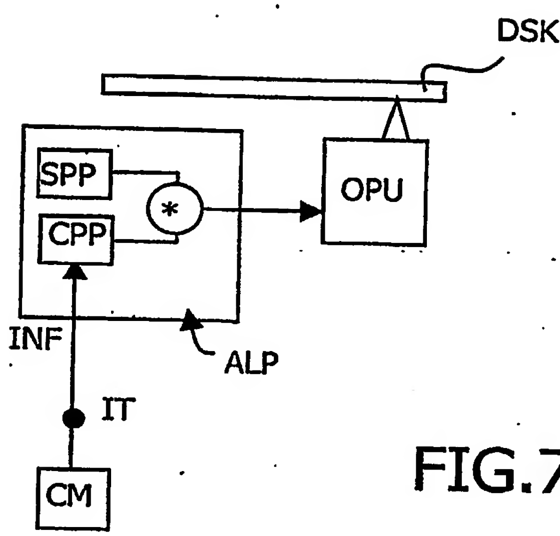

FIG.7